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CSM BATTERY CHARGER MODEL

Guidance and Performance Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

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By James McClellan and R. E. Stokes
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1.0 SUMMARY AND INTRODUCTION

The purpose of this note is to present the design concept, assumptions, logic flow chart, program listing, and a sample case of the CSM battery charger model. Basically, the model simulates the battery charger during the charge cycle of the entry and postlanding batteries. The model is to be used in the CSM SEENA program so that more accurate CSM entry and postlanding battery power profiles may be generated. The model will also be used to simulate the CSM battery charger in the AAP EPS program.

2.0 SYMBOLS

A, B, C, E, F	tables of data for charge rate curve
AF	degradation factor
A-h	ampere hours
AHD	amp-hours discharged from Batt I
AHS(I)	amp-hours present in Batt I
AHST	present amp-hour status
AMP(I)	amps into Batt I
Batt I	CSM entry and postlanding batteries
CALC	intermediate variable used for comparison only
CP	intermediate variable (%) read from C table and used to calculate C (C = CP * B)
CSTS	CST1 + CST2
CST1	area under charge rate curve from 0 to E
CST2	area under charge rate curve from E to F
DELCH	delta charge, charge under curve from TA to T
FT	intermediate variable read from F table and used to calculate F (F = FT + E)
FULCH	full recharging capability of Batt I (near 40 for the first five recharges)
JBATT(I)	0 if Batt I is OFF 1 if Batt I is ON
NCH	number of times the charger has been used on Batt I
NCHRG(I)	number of times the charger has been used on Batt I
ONAH(I)	amp-hour status of Batt I at ON-time
ONAHS	amp-hour status at ON-time

ONT	ON time
ONTIM(I)	ground elapsed time (g.e.t.) at which the charger was put on Batt I
PT	present ground elapsed time (g.e.t.)
RE	area under charge rate curve from F to G
SEENA	spacecraft electrical energy network analysis
T	time variable for time axis in charge rate curve (T = PT - ONT)
TA	time of the last solution relative to the time axis of the charge rate curve
TD(I)	ground elapsed time (g.e.t.) of the last major discharge of Batt I
TLD	time of the last discharge
TLS	time of the last solution
TL(I)	ground elapsed time (g.e.t.) of the last solution for the charger on Batt I
VI	volt-amp characteristic of charger
VOLT(I)	voltage on Batt I
XY1	y-intercept on line segment with slope X1
XY2	y-intercept of line with slope X2
X1	slope of line segment from (O, A) to (E, B)
X2	slope of line segment from (E, B) to (F, C)

3.0 BATTERY CHARGER DESCRIPTION

The battery charger is of constant voltage output design. The battery charger is supplied with both a dc voltage source of between 25 to 30 volts and an ac voltage source of 400 Hz three-phase 115 volts to produce a 40-volt output charging EMF. A two-stage differential amplifier, Schmitt trigger, current sensing resistor, and voltage amplifier comprise the battery charger logic network which sets up the initial conditions for the battery charger operation. A switching transistor, current amplifier, sensing resistor, and switching choke complete the basic battery charger circuit. The fundamental circuit logic flow is presented in figure 3-1. When the battery charger is turned on, the first stage of the differential amplifier (comparator) is in the ON mode. The second stage of the comparator would then be in the OFF mode, which in turn sets the first stage of the Schmitt trigger to the ON mode with the second stage off. This circuit configuration produces maximum base drive on the current amplifier which turns the switch transistor on. At this time, the circuitry which permits the charging current to flow into the battery is closed. Charging current flows from the transformer rectifier circuit through the switching transistor, current sensing resistor, and the switching choke. The voltage drop across the current sensing resistor increases as the charging current increases. When the voltage drop reaches a specific level, the second stage of the comparator is switched automatically to the ON mode, and the first stage is switched to the OFF mode. The voltage amplifier in turn is switched off, which reverses the operation mode of the Schmitt trigger. Because the first stage of the Schmitt trigger is off and the second stage is on, the switching transistor is turned off, which interrupts the charging current path. As a result, the electromagnetic field in the choke collapses, discharges into the battery being charged, then passes through the switching diode, and goes through the sensing resistor. As the field in the choke continues to collapse, the EMF in the choke decreases, and the voltage drop across the sensing resistor decreases until the voltage has again reached a specific low level and the comparator mode of operation is reversed (stage 1 is ON, and stage 2 is OFF). The initial conditions have been reset, and one cycle of battery charging has been completed. As a result of a series-connected inductor in the charging circuit, the output current of the charger remains free from variation except for a small amount through the current sensing resistor.

In summary, the battery charger output current is regulated by the sensing resistor until the battery voltage reaches 37.0 volts. At a battery voltage of 37.0 volts, the voltage sensor circuit becomes unbiased and, in conjunction with the sensing resistor, provides a signal for cycling the battery charger. Battery charging is terminated when the battery voltage reaches 39.8 volts.

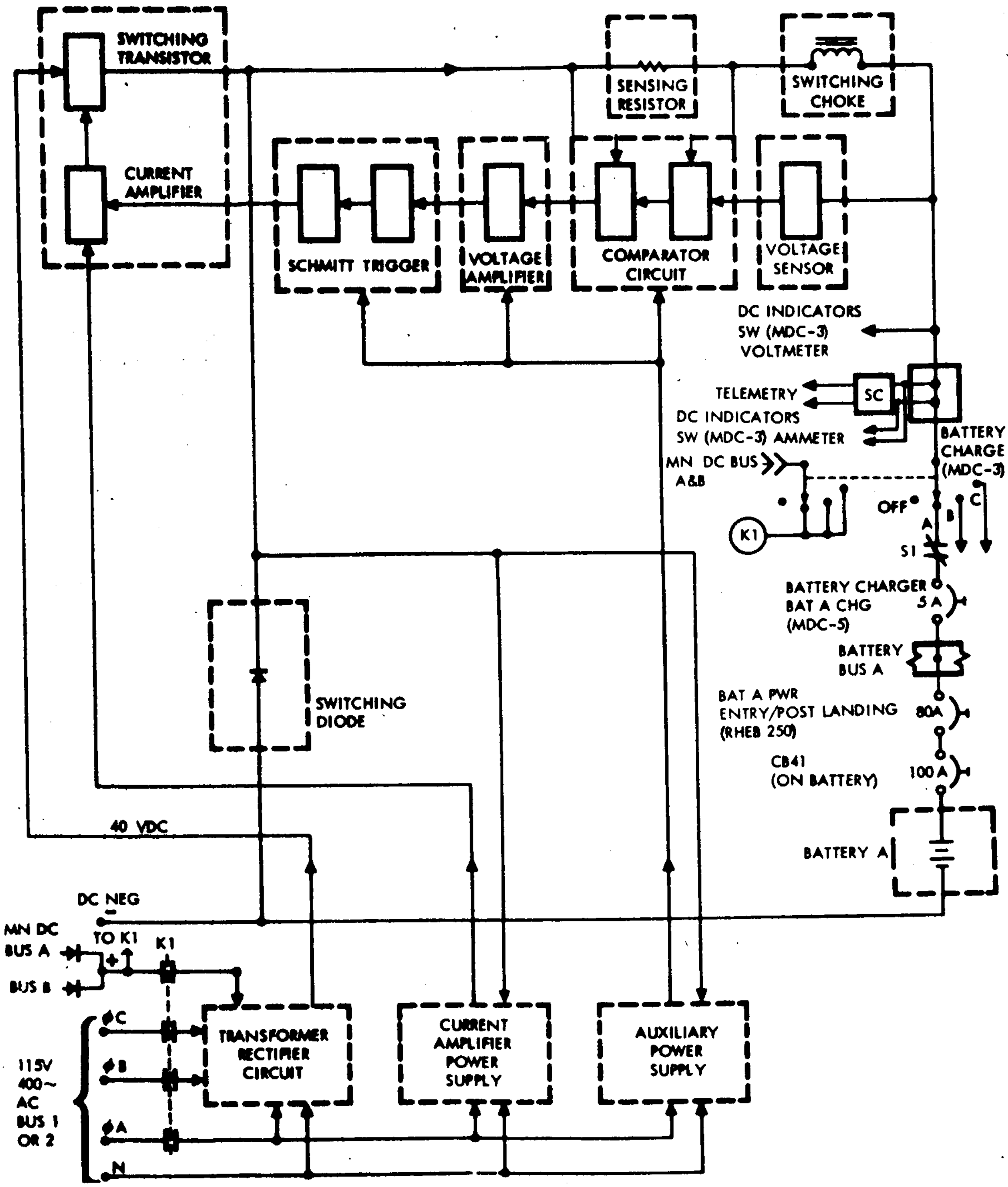


Figure 3-1.- Block diagram of the CSM battery charger circuit.

4.0 ASSUMPTIONS AND DESIGN

The battery charger model is an empirical model. It was designed from actual test and performance data obtained from reference 1. The battery charger constraining functions were determined from the actual test data. Various test data trends were noted and are represented in the plots of section 9. A generalized battery charger output curve was determined from the performance data (fig. 4-1). The generalized output curve was broken into three sections so that it could be mathematically manipulated by the initial conditions of the battery being charged. When the initial conditions of the battery are known, the battery charger output characteristic can be calculated. The maximum charge time for 100 percent battery recharge can be determined from the charger output characteristic as well as from the battery charger voltage-current characteristics for any time during the recharge cycle of the battery. The battery also can be recharged in a number of charge periods by calculation of the battery charger characteristic output curve for each recharge period.

The battery charger model is based upon several assumptions which are discussed in this section. After the initial inspection of the data in reference 1, it can be determined that the battery charger recharge capability is a function of three variables: the ampere-hours discharged from the battery, the time from the end of the last battery discharge, and the time from the end of the last battery charge. The effect of the time from the end of the last battery charge is assumed to be an insignificant factor in the battery charger model. A 100 percent battery charger efficiency is assumed; that is, all of the energy supplied to the battery by the battery charger is used to reenergize the depleted battery. The maximum ampere-hour capacity of the battery is assumed to decrease by 10 percent after five cycles of battery charge and recharge. This decrease simulates battery degradation after several usage cycles. Battery loads of less than 1 ampere per battery will not be considered when the time from the end of the last discharge is being determined. The battery charger input power does not vary as a function of output current in the SEENA CSM program. The AAP CSM battery charger model will have an input power that varies with fluctuations in output charge current. The battery charger input voltage-current levels are indicated in figure 4-2 as a function of the output or charging current.

The general battery charger output or charging curve is shown in figure 4-2. The charger current is plotted against the time the charger is on the battery. All the coordinates except 0.4 can be obtained from the various plots in section 9. The 0.4-ampere coordinate is a test data value which guarantees complete battery recharge. Coordinates A and B are functions of the ampere-hours discharged from the battery and of the time from the end of the last battery discharge. All the data necessary for these coordinates are given in figures 9-1 and 9-2. Coordinate C is a function of the ampere-hours discharged from the battery and is illustrated in figure 9-3. The data in figure 9-3 are expressed as a factor that is multiplied by the value of coordinate B to obtain coordinate C. Coordinate E is a function of the time from the last discharge. The rise time of the peak current, which is coordinate E, is presented in figure 9-4 as a function of the time from the end of the last discharge. Coordinate F is presented in figure 9-5 as a function of ampere-hours discharged from the battery. The time given on the vertical scale of figure 9-5 is relative to coordinate E. Coordinate G is a function of coordinates A, B, C, E, F, and the total ampere-hours needed to completely recharge the battery.

$$G = \frac{2[\text{A-h needed to completely recharge the battery}] + F}{C + 0.4}$$

Because the battery charger output curve can be determined, the effect of the charger on the battery for any period of time can be determined.

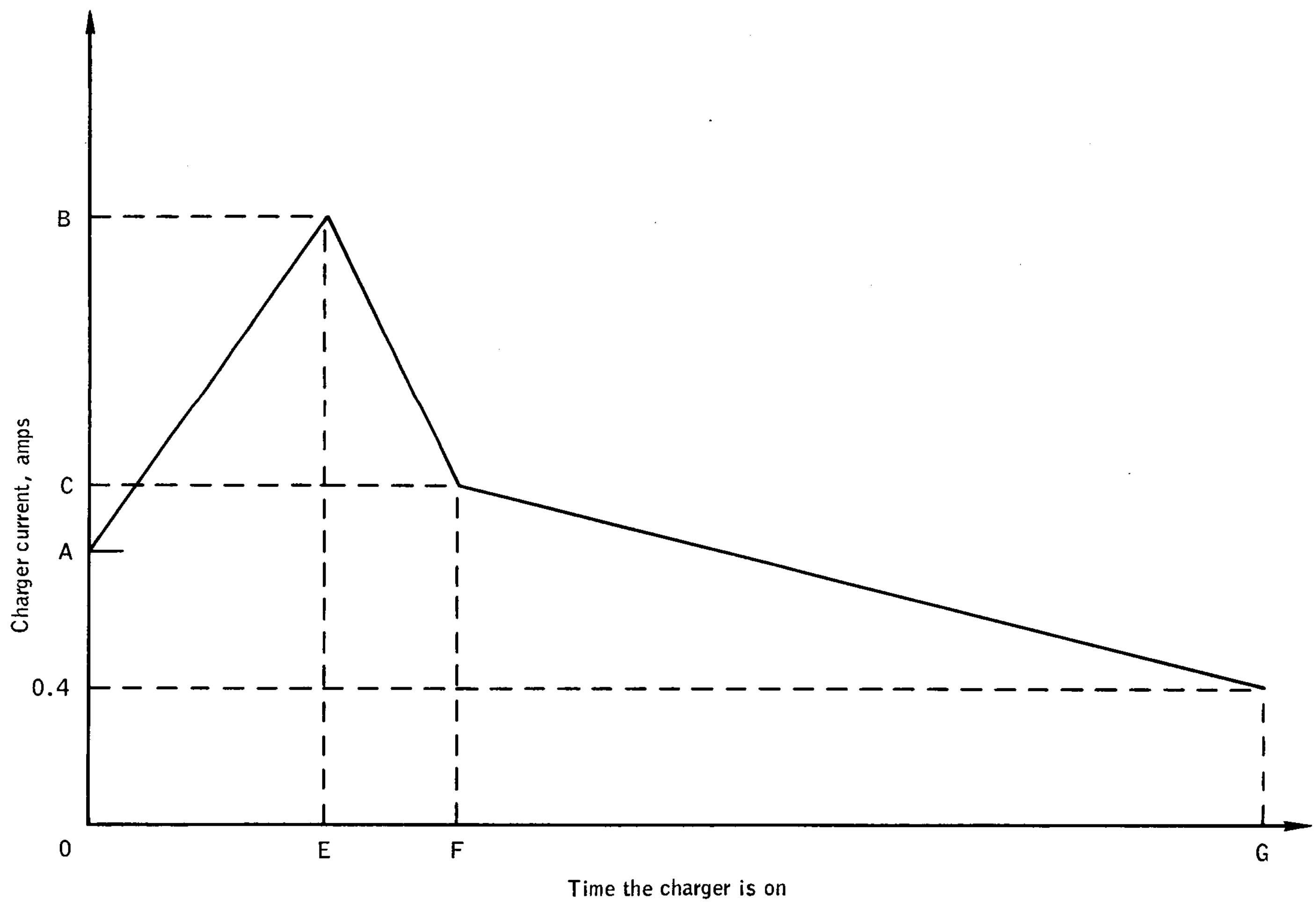


Figure 4-1.- Battery charger general recharge rate curve.

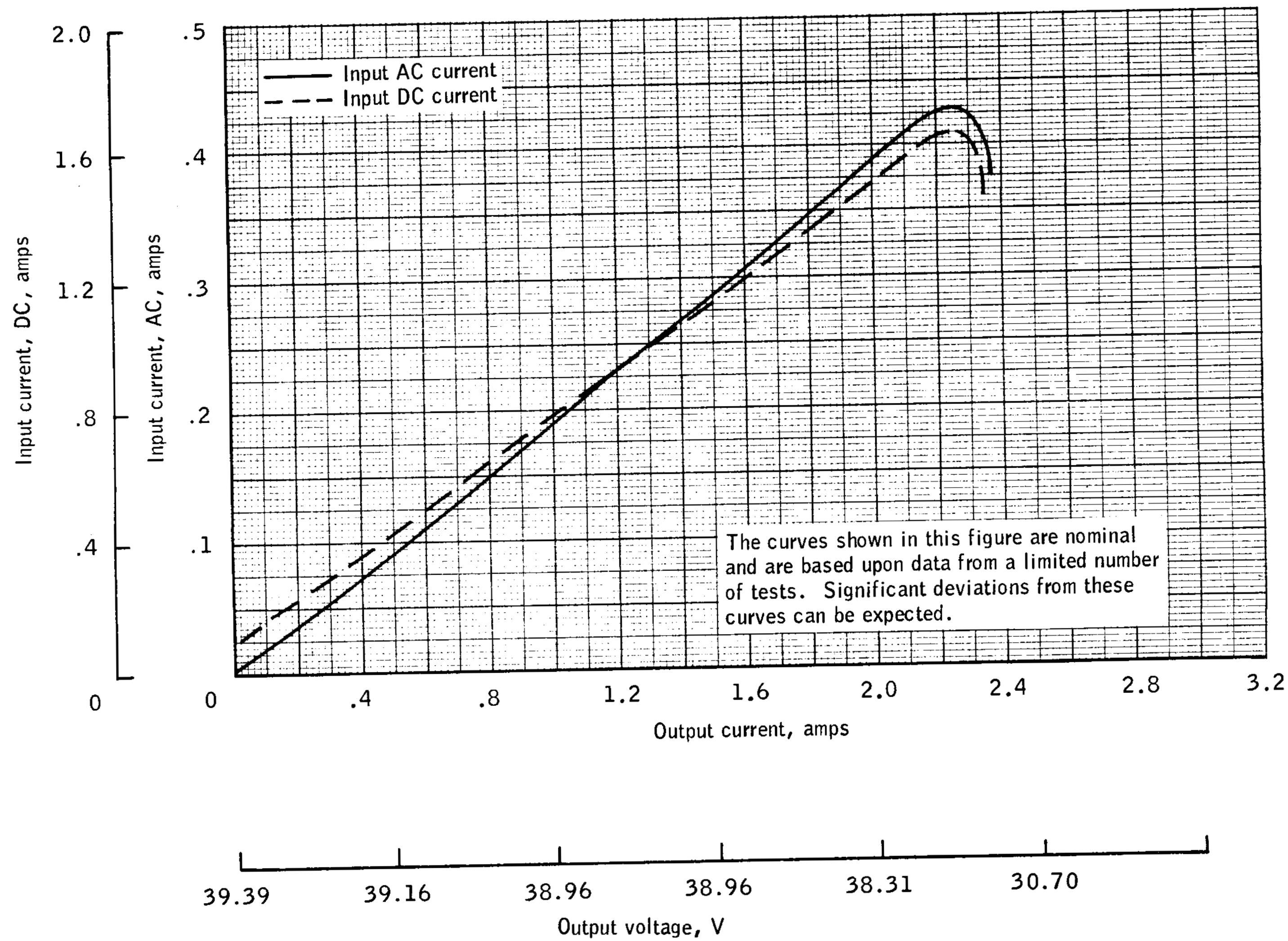


Figure 4-2.- Nominal battery charger input/output characteristics.

5.0 COMPUTER PROGRAM DESCRIPTION

The program flow is divided into six major sections in the general flow diagram. These sections emphasize the overall operation of the model from the inputs, through the checks and calculations, and finally to the update and outputs to the main program. Each section will be considered individually in the discussion which follows.

The inputs to the battery charger model consist of three types.

a. Data curves: these six curves have been extracted from test data on the charger and provide the program with the necessary information to calculate the characteristics of the battery.

b. Status of the batteries: this vital information is stored in arrays TL, AHS, TD, ONAH, ONTIM.

c. Charger ON: These data indicate which battery is being charged and at what time a solution point is desired. The form of this input is arranged in a card as follows.

	Columns		
	12	14	16
Present time Cols 1-10	Battery A	B	C
	"1" if charger is on		

The program reads the information in columns 12, 14, and 16 into a three-element array JBATT(3). Then a DO loop is used to compare each element of JBATT to 1. For example, if Batt A is being charged, then JBATT(1) is equal to 1 and control leaves the DO loop; all status information on battery A would be transferred into nonsubscripted names ONT, TLD, TLS, NCH, ONAHS, AHST. At this time, the program checks to see if this is the first time solution during the recharge cycle. If so, a counter that registers the number of charges is incremented. Then the program checks to see how many times battery A has been recharged. If it has been charged more than five times, then an adjustment is made so that the battery can charge back up to only 90 percent of the original charge, which is 36 A-h. This maximum charge is called FULCH in the program.

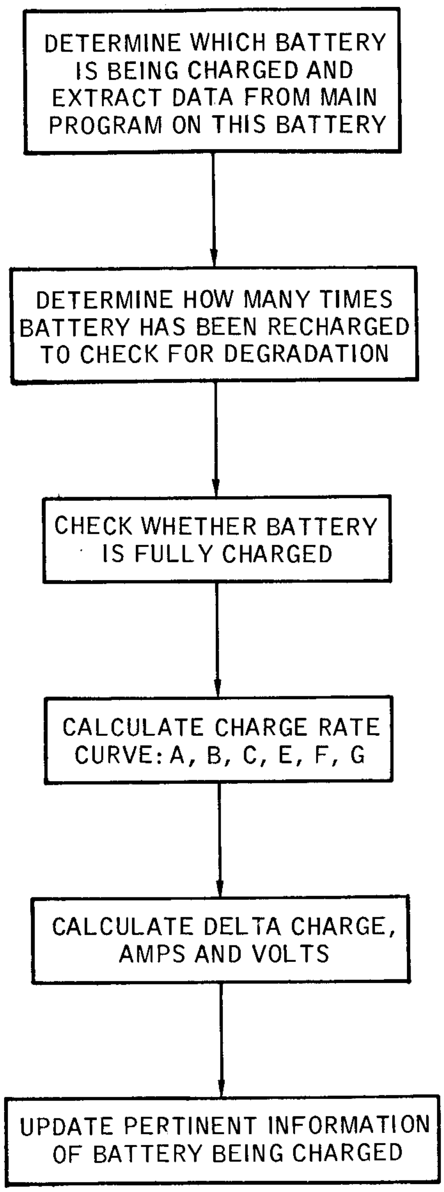
Next, the program checks to see if battery A is fully charged. This check is made by a comparison of AHST + 0.001 to FULCH. The 0.001 is added to insure that the test does not fail in an insignificant decimal place.

Then the program proceeds to the calculation phase. First, the charge rate curve is calculated by interpolation of the curves A, B, C, E, and F which are functions of TLD and AHD. Then by integration from the time of last solution to the present time, the delta charge is calculated. Two checks are made to insure that the charge does not exceed the full charge and that the charger current is 0.4 amps at full charge. The program examines the amount of charge necessary to return to full charge and checks to see that the time to obtain this charge is greater than F. If not, the program will force a solution to come at full charge and 0.4 amps. Otherwise, the manner in which the time G is calculated will insure that the full charge will come at 0.4 amps.

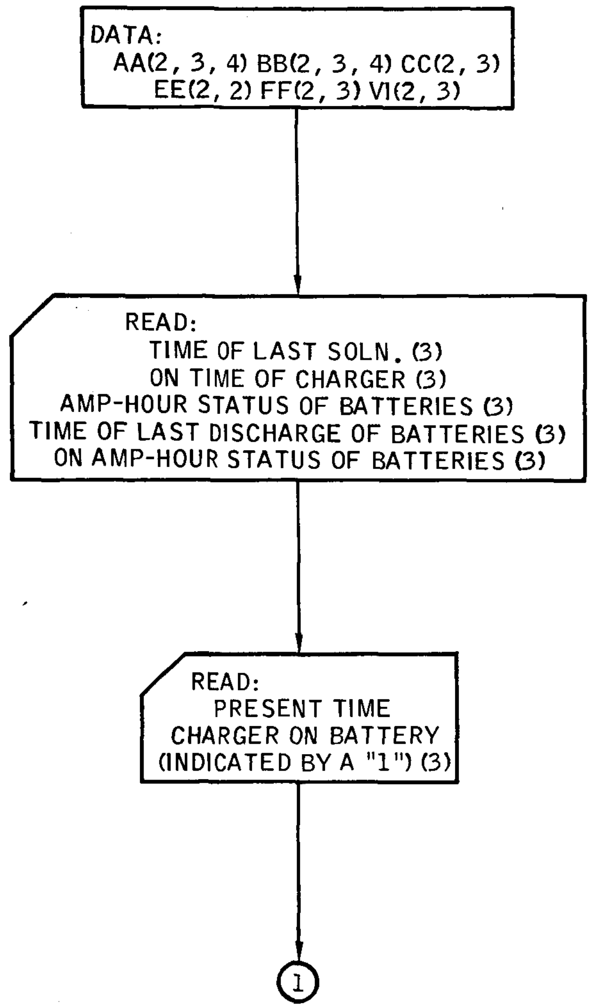
The output voltage is calculated by interpolation of the volt-amp characteristic curve of the charger. Then all pertinent information concerning the battery being charged is updated and stored for usage in the main program.

6.0 FLOWCHART

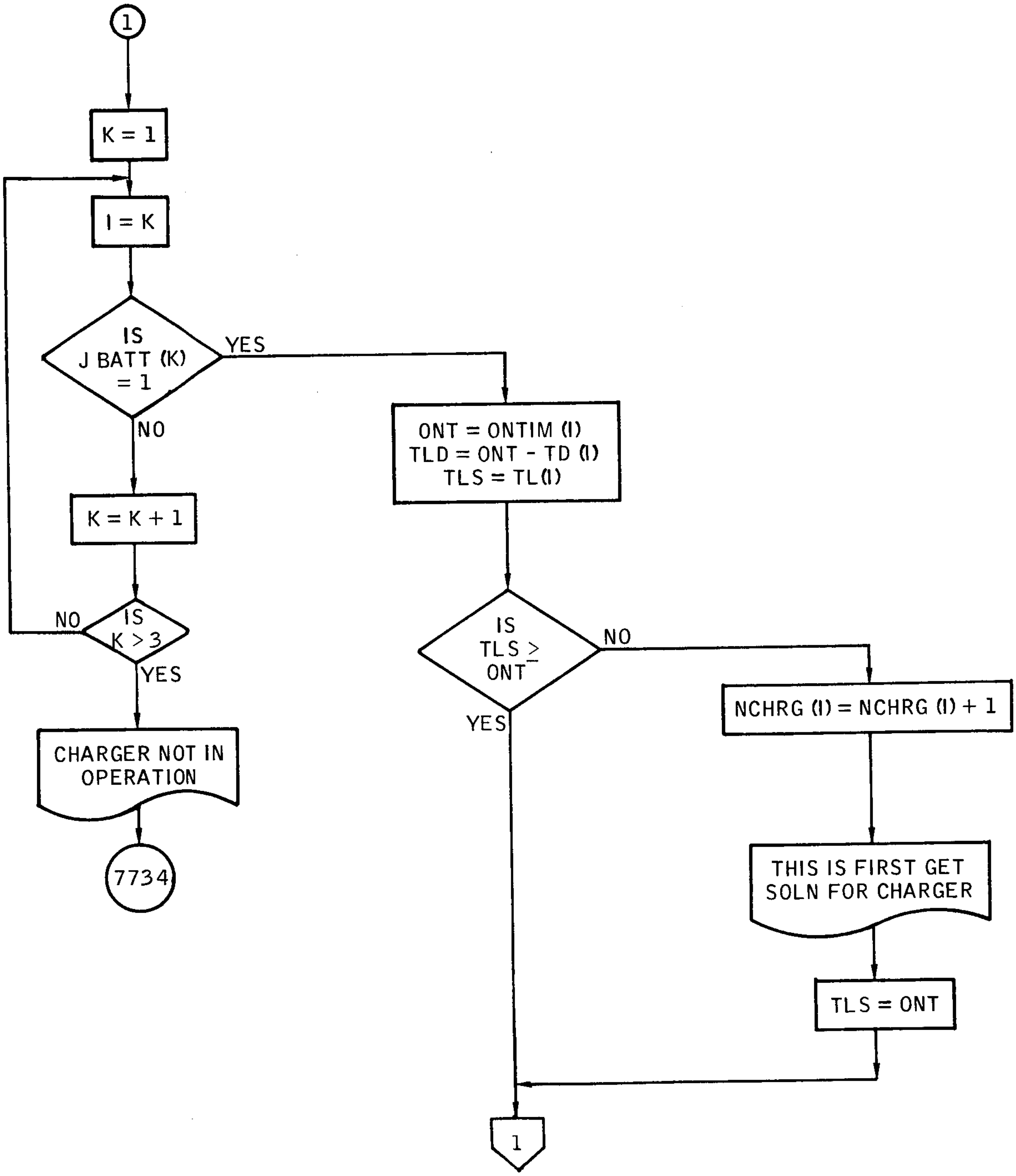
The battery charger program flow chart is presented in this section.



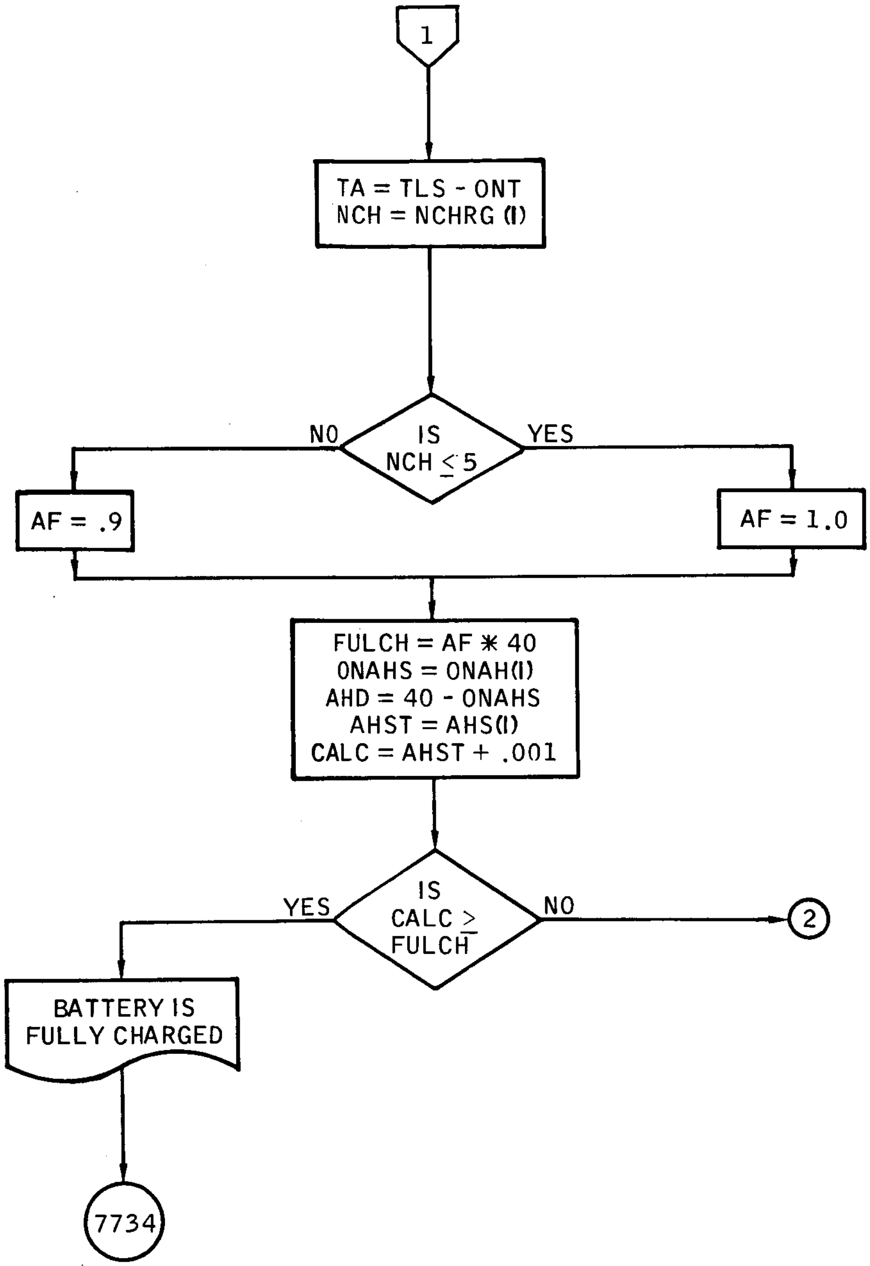
GENERAL FLOW



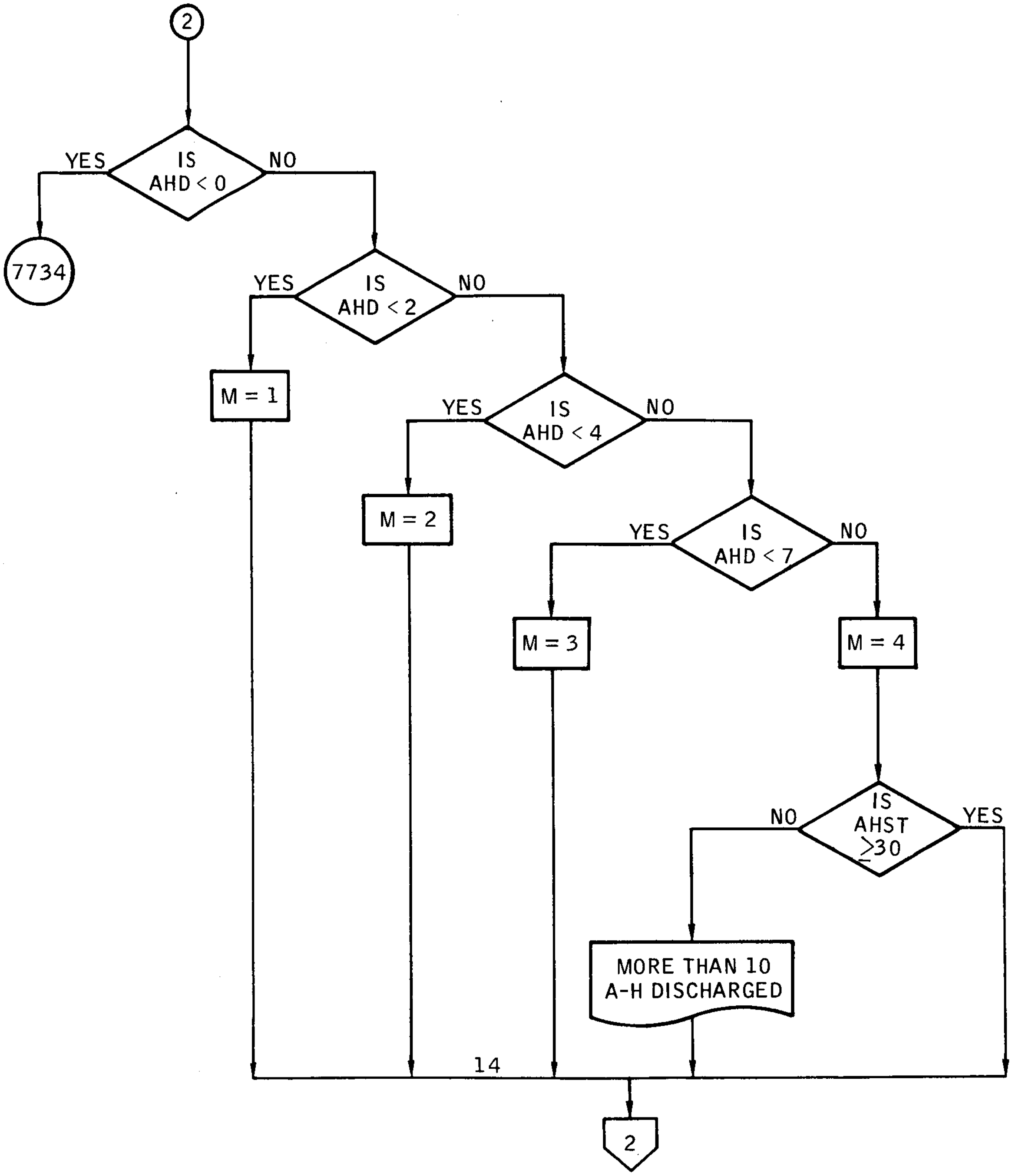
Flow Chart.- Inputs.



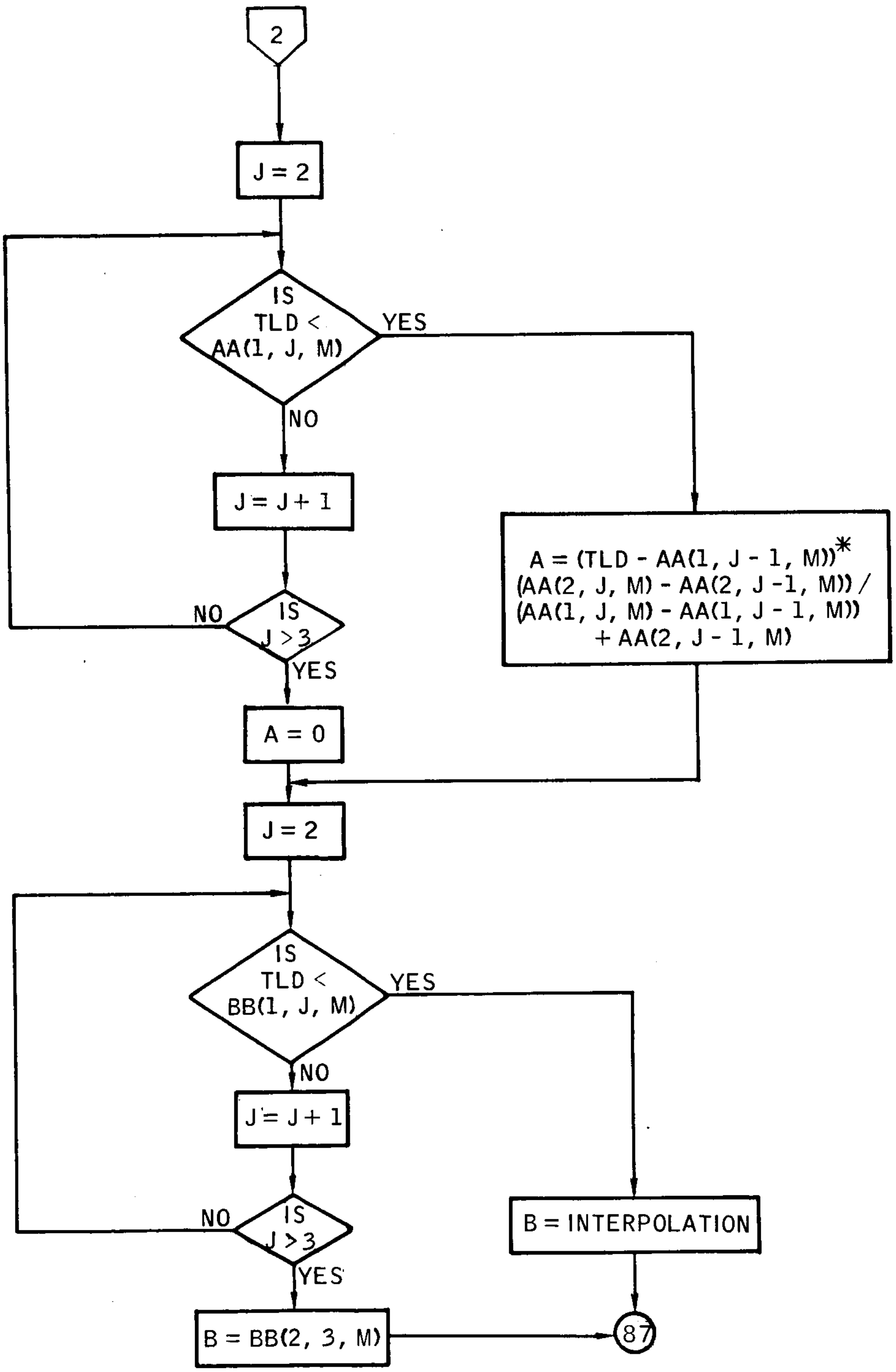
Flow Chart .- Continued.



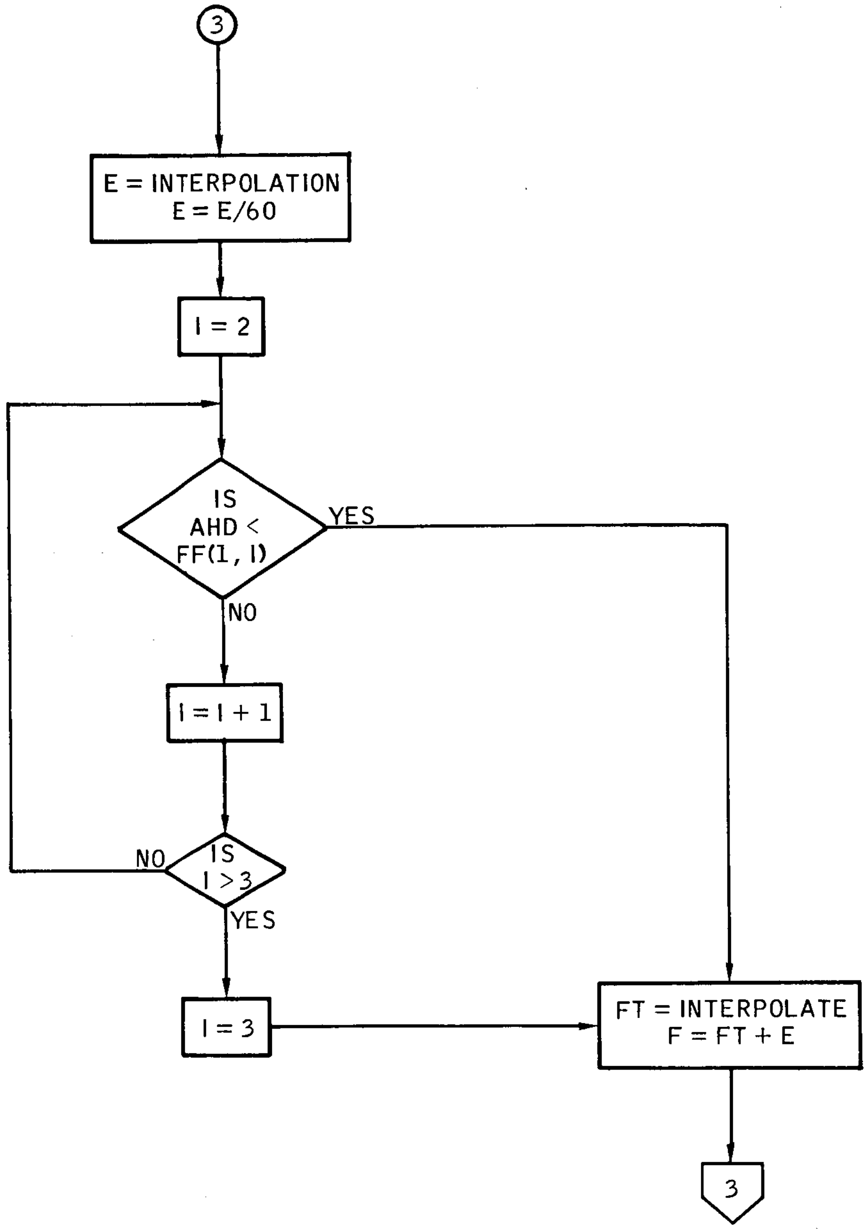
Flow Chart .- Continued.



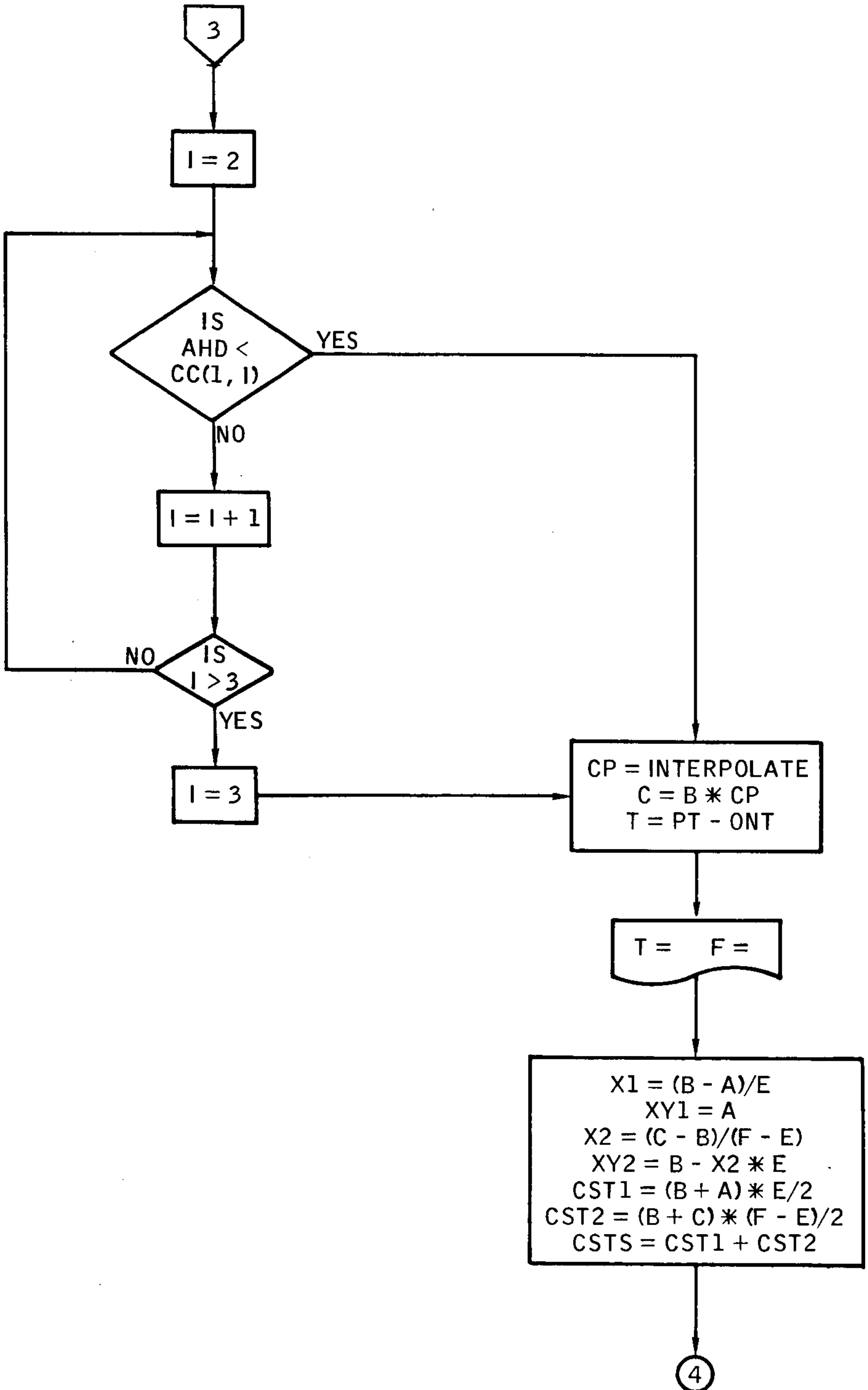
Flow Chart.- Continued.



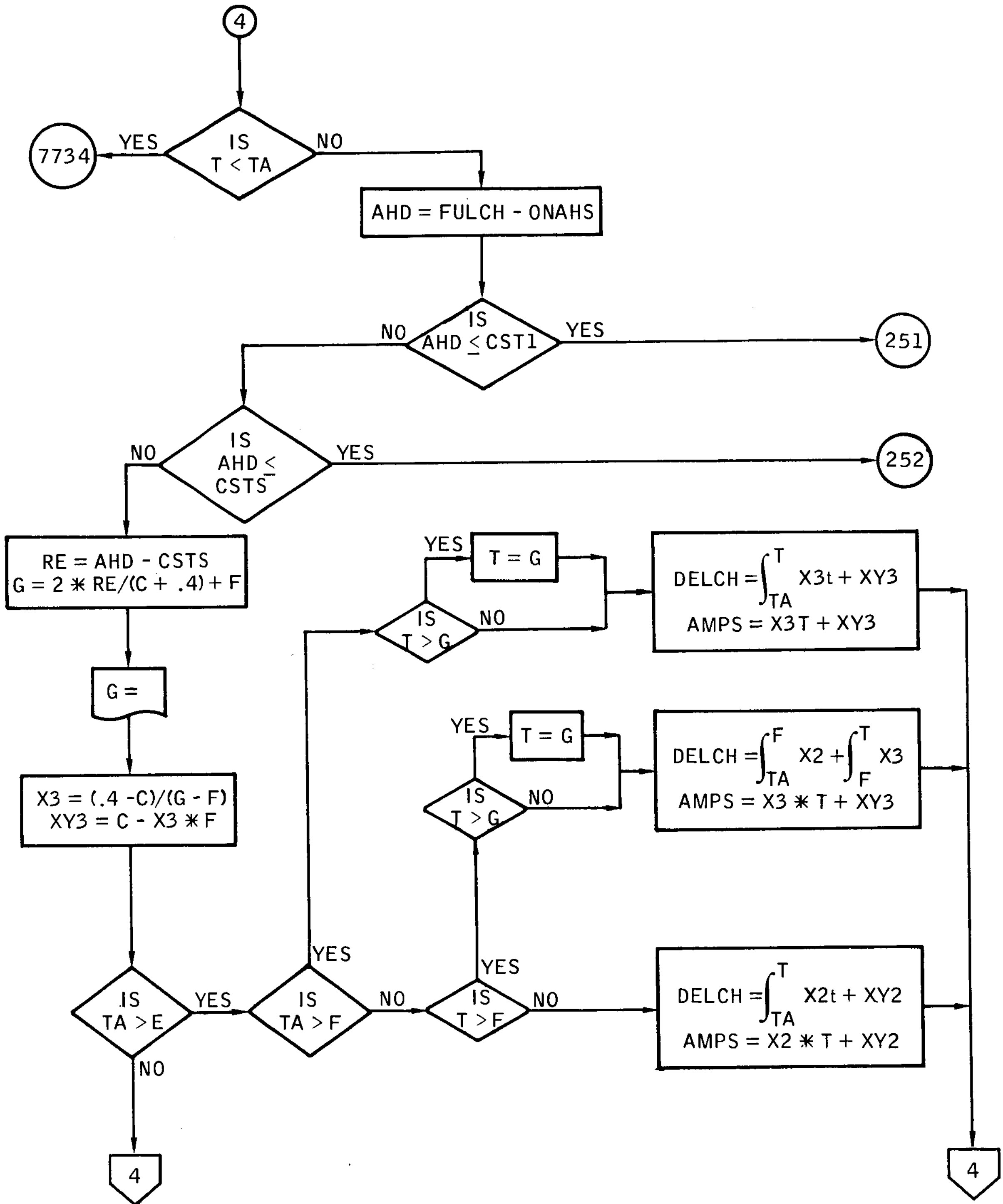
Flow Chart. - Continued.



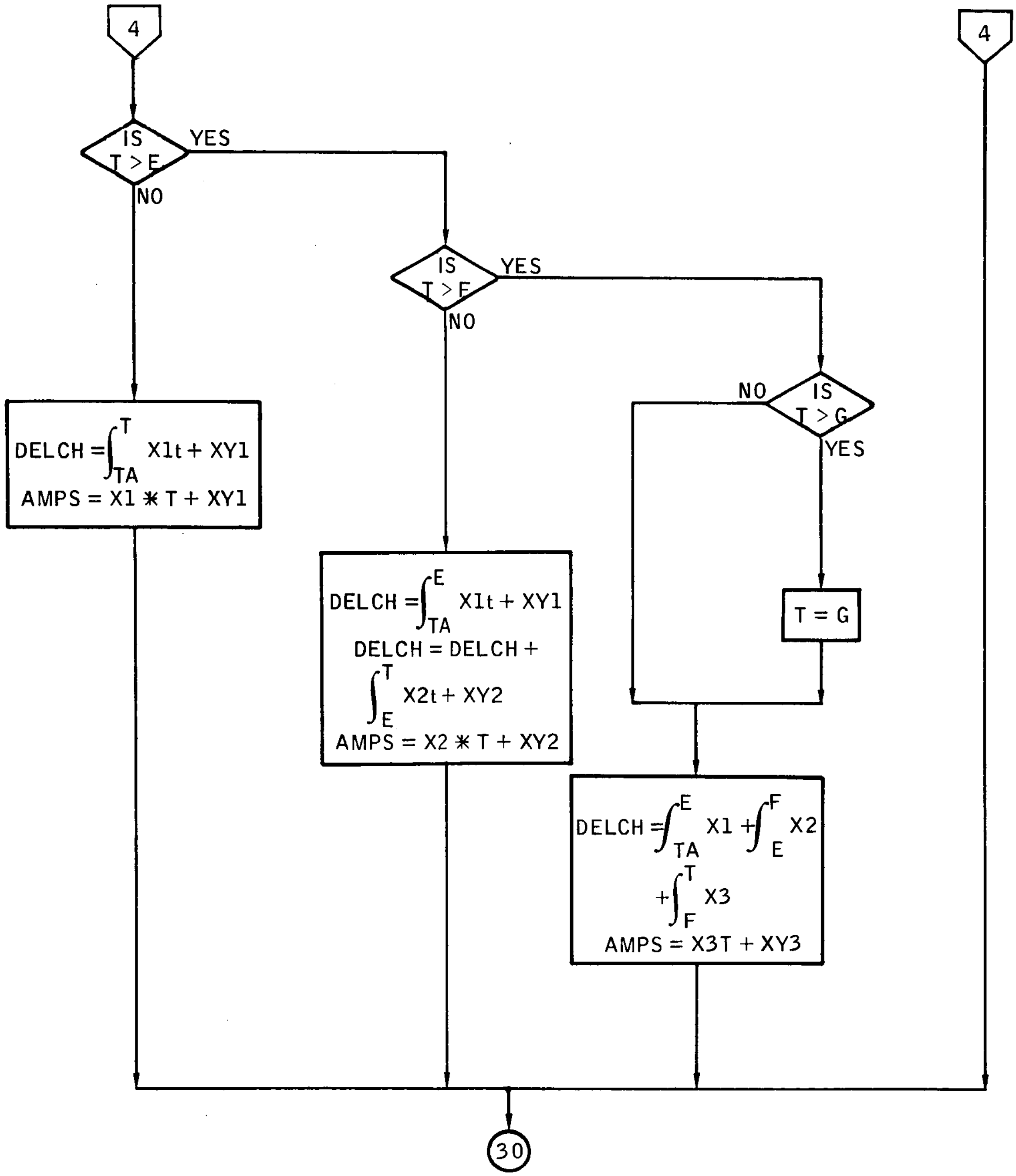
Flow Chart . - Continued.



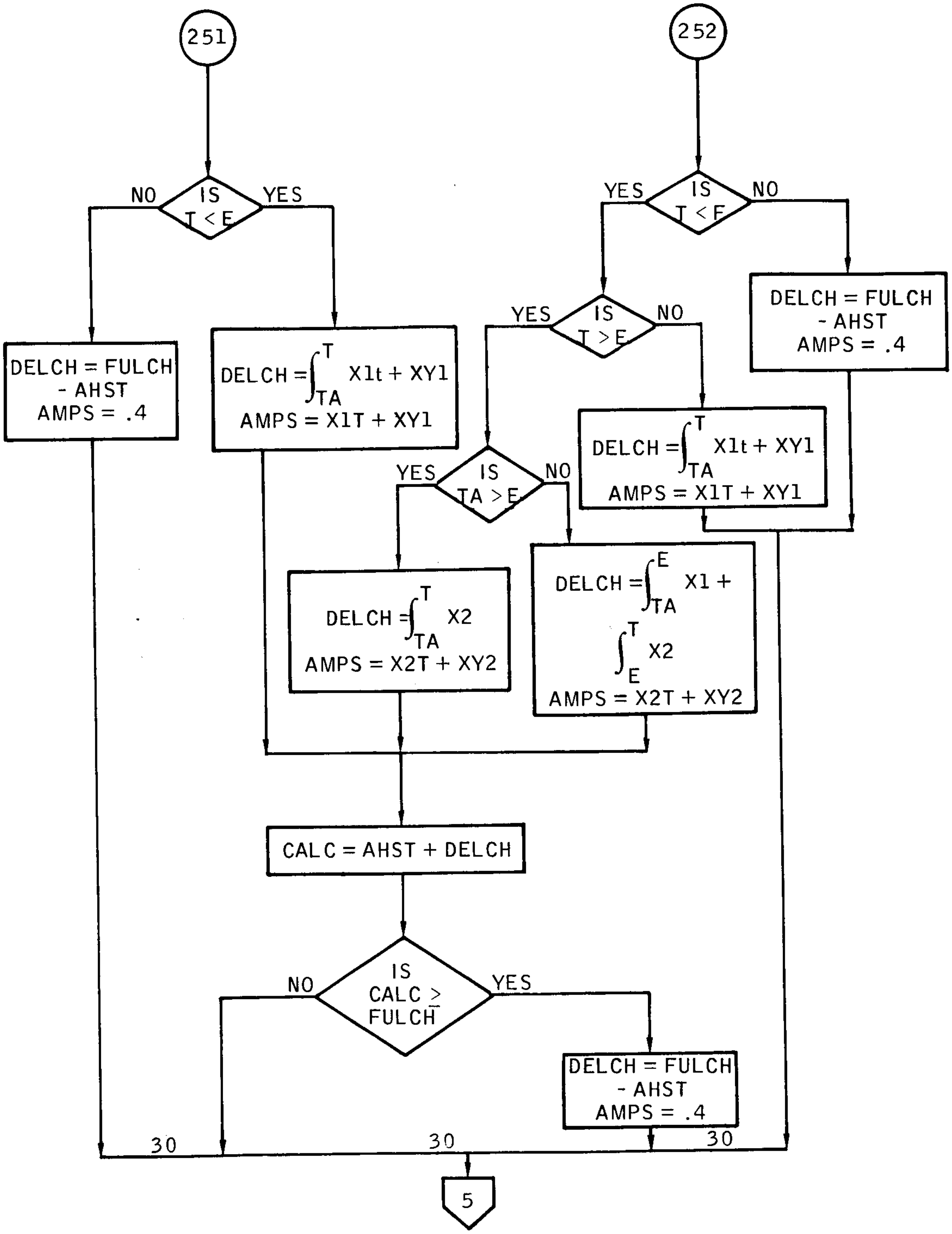
Flow Chart .- Continued.



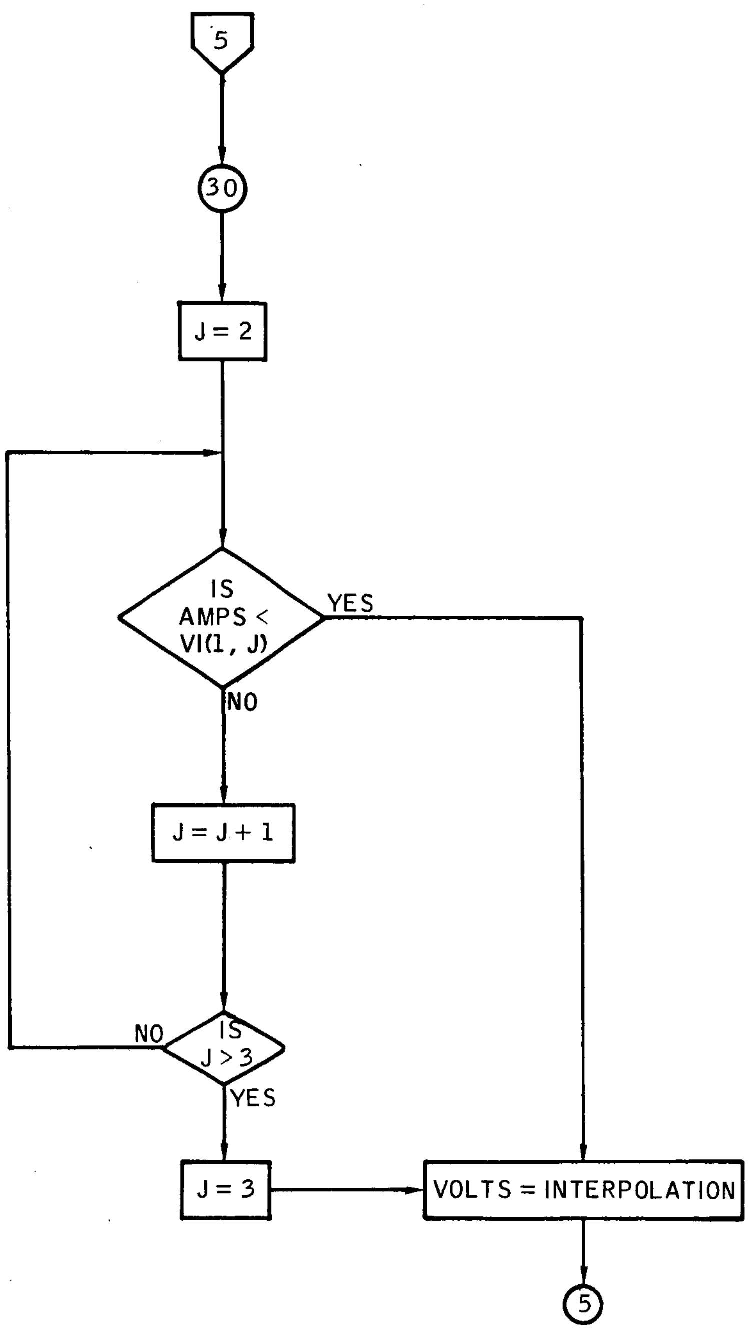
Flow Chart .- Continued.



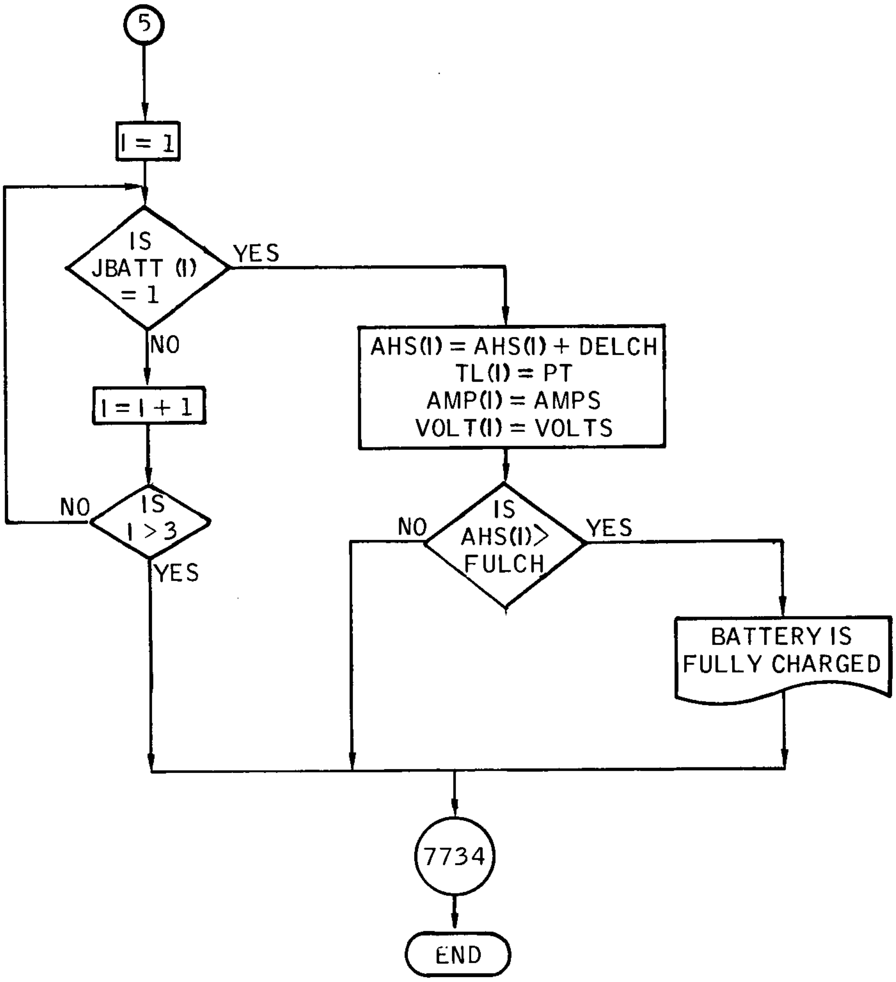
Flow Chart.- Continued.



Flow Chart. - Continued.



Flow Chart - Continued.



Flow Chart.- Concluded.

7.0 BATTERY CHARGER MODEL COMPUTER PROGRAM LISTING

```
@ FOR MAIN                                                      09:34:18
UNIVAC 1108 FORTRAN V LEVEL   2206 0018 F5018H
THIS COMPILATION WAS DONE ON 30 JUN 69 AT 09:34:19

  MAIN PROGRAM

    STORAGE USED (BLOCK, NAME, LENGTH)

          0001   *CODE    001571
          0000   *DATA    000404
          0002   *BLANK   000000

  EXTERNAL REFERENCES (BLOCK, NAME)

          0003   NRDU$
          0004   NI01$
          0005   NI02$
          0006   NWDU$
          0007   NSTOP$

  STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)
```

0000 000222 1F	0001 000256 10L	0000 000211 100F	0000 000224 102F	0000 000231 110F
0000 000241 12F	0001 000014 120G	0001 000021 124G	0001 000026 130G	0001 000033 134G
0001 000261 14L	0001 000040 140G	0001 000052 147G	0001 000321 151L	0001 000057 153G
0001 000302 1AL	0001 000065 161G	0001 000076 166G	0001 000104 174G	0001 000347 18L
0001 000167 16bL	0001 000171 169L	0001 000414 20L	0000 000254 202F	0000 000257 203F
0001 000450 22L	0001 000152 24L	0001 001071 25L	0001 000647 251L	0001 000662 252L
0001 000675 253L	0001 000722 254L	0001 000754 255L	0001 001027 256L	0001 001053 257L
0001 001144 26L	0001 000267 265G	0001 001223 27L	0001 000332 277G	0001 001262 28L
0001 001337 29L	0001 000123 3L	0001 001372 30L	0001 000401 313G	0001 001465 32L
0001 000435 325G	0001 001504 34L	0000 000307 35F	0000 000247 401F	0001 001375 501G
0001 001455 526G	0001 001521 551G	0001 001526 555G	0001 001533 561G	0001 001540 565G
0001 001552 573G	0001 001557 577G	0001 000250 6L	0001 001063 621L	0001 001070 622L
0000 000324 66F	0001 001511 7734L	0001 000253 8L	0001 000366 87L	0000 000217 91F
0000 000314 92F	0001 001410 97L	0000 R 000163 A	0000 R 000022 AA	0000 R 000153 AF
0000 R 000156 AHD	0000 R 000125 AHS	0000 R 000157 AHST	0000 R 000003 AMP	0000 R 000207 AMPS
0000 R 000164 B	0000 R 000062 BB	0000 R 000171 C	0000 R 000160 CALC	0000 R 000114 CC
0000 R 000170 CP	0000 R 000201 CSTS	0000 R 000177 CST1	0000 R 000200 CST2	0000 R 000206 DELCH
0000 R 000165 E	0000 R 000102 EE	0000 R 000167 F	0000 R 000106 FF	0000 R 000166 FT
0000 R 000154 FULCH	0000 R 000203 G	0000 I 000145 I	0000 I 000141 IS	0000 I 000162 J
0000 I 000122 JEATT	0000 I 000144 K	0000 I 000161 M	0000 I 000142 MANY	0000 I 000152 NCH
0000 I 000000 NCHRG	0000 R 000136 ONAH	0000 R 000155 ONAHS	0000 R 000146 ONT	0000 R 000133 ONTIM
0000 R 000143 PT	0000 R 000202 RE	0000 R 000172 T	0000 R 000151 TA	0000 R 000130 TD
0000 R 000017 TL	0000 R 000147 TLD	0000 R 000150 TLS	0000 R 000011 VI	0000 R 000006 VOLT
0000 R 000210 VOLTS	0000 R 000174 XY1	0000 R 000176 XY2	0000 R 000205 XY3	0000 R 000173 X1
0000 R 000175 X2	0000 R 000204 X3			

```
00100      1*     C       BATTERY CHARGER
00100      2*     C
```

```
00100        C
00101              DIMENSION NCHRG(3),AMP(3),VOLT(3),VI(2,3)
00103              DIMENSION TL(3),AA(2,3,4),BB(2,3,4),EE(2,2),FF(2,3),CC(2,3)
00104              DIMENSION JBATT(3),AHS(3),TD(3),ONTIM(3),ONAH(3)
00105              DATA VI,NCHRG/0.,40.,2.2,37.,2.8,0.,6,0,0/
00110              DATA AA,BB,CC,EE,FF/0.,2.3,2.7,.6,11.2,0.,0.,2.3,4.6,.8,15.,0.,0.,
00110             22.3,6.3,1.06,17.3,0.,0.,2.3,7.45,1.21,20.9,0.,0.,2.3,5.2,1.36,20.,
00110             3.77,0.,2.3,6.1,1.51,20.,1.14,0.,2.3,6.5,1.83,20.,1.52,0.,2.3,7.3,
00110             42.08,20.,2.,0.,.33,6.8,.5,10.,.5,0.,0.,16.,12.5,0.,.4,3.9,1.4,9.,
00110             54./
00110        C
00110        C
00116           75 READ(5,100)TL,ONTIM,AHS,TD,ONAH
00144          100 FORMAT(3F10.3/3F10.3/3F10.3/3F10.3/3F10.3)
00145              READ(5,91)AMP,VOLT
00157           91 FORMAT(3F10.3/3F10.3)
00160              DO 77 MANY=1,15
00163              READ(5,1)PT,JBATT
00172            1 FORMAT(F10.3,3I2)
00173              DO 2 K=1,3
00176              I = K
00177              IF(JBATT(K).EQ.1)GO TO 3
00201            2 CONTINUE
00203              WRITE(6,102)
00205          102 FORMAT(25H CHARGER NOT IN OPERATION)
00206              GO TO 7734
00207            3 ONT = ONTIM(I)
00210              TLD = ONT - TD(I)
00211              TLS= TL(I)
00212           23 IF(TLS.GE.ONT)GO TO 24
00214              NCHRG(I) = NCHRG(I) + 1
00215              WRITE(6,110)
00217          110 FORMAT(39HOTHIS IS FIRST GET SOLUTION FOR CHARGER)
00220              TLS = ONT
00221           24 TA = TLS - ONT
00222              NCH = NCHRG(I)
00223              IF(NCH.LE.5)GO TO 188
00225              AF = .9
00226              GO TO 189
00227          188 AF = 1.0
00230          189 FULCH = AF * 40.
00231              ONAHS = ONAH(I)
00232              AHD = 40. - ONAHS
00233              AHST = AHS(I)
00234              CALC = AHST + .001
00235              IF(CALC.GE.FULCH)GO TO 34
00235        C
00235        C     SELECTION OF CURVE
00235        C
00237              IF(AHD.LT.0.0)GO TO 7734
00241              IF(AHD.LT.2.0)GO TO 6
00243              IF(AHD.LT.4.0)GO TO 8
00245              IF(AHD.LT.7.0)GO TO 10
00247              M=4
00250              IF(AHST.GE.30.)GO TO 14
00252           13 WRITE(6,12)
00254           12 FORMAT(28H MORE THAN 10 A-H DISCHARGED)
00260              GO TO 14
```

```
00256        6 M=1
00257          GO TO 14
00260        8 M=2
00261          GO TO 14
00262       10 M=3
00263          GO TO 14
00263   C
00263   C      CALCULATION OF POINT A
00263   C
00264       14 DO 15 J=2,3
00267          IF(TLD.LT.AA(1,J,M))GO TO 16
00271       15 CONTINUE
00273          A = 0.
00274          GO TO 151
00275       16 A=(TLD - AA(1,J-1,M))*(AA(2,J,M) - AA(2,J-1,M))/(AA(1,J,M) - AA(1,
00275         2J-1,M)) + AA(2,J-1,M)
00275   C
00275   C      CALCULATION OF POINT B
00275   C
00276      151 DO 17 J=2,3
00301          IF(TLD.LT.BB(1,J,M))GO TO 18
00303       17 CONTINUE
00305          B = BB(2,3,M)
00306          GO TO 87
00307       18 B = (TLD - BB(1,J-1,M))*(BB(2,J,M) - BB(2,J-1,M))/(BB(1,J,M) - BB(
00307         21,J-1,M)) + BB(2,J-1,M)
00307   C
00307   C      CALCULATION OF E
00307   C
00310       87 E=(TLL-EE(1,1))*(EE(2,2)-EE(2,1))/(EE(1,2)-EE(1,1))+EE(2,1)
00311          E = E/60.
00311   C
00311   C      CALCULATION OF F
00311   C
00312          DO 19 I=2,3
00315          IF(AHD.LT.FF(1,I))GO TO 20
00317       19 CONTINUE
00321          I=3
00322       20 FT=(AHD-FF(1,I-1))*(FF(2,I)-FF(2,I-1))/(FF(1,I)-FF(1,I-1))+FF(2,I-
00322         21)
00323          F = FT + E
00323   C
00323   C      CALCULATION OF C
00323   C
00324          DO 21 I=2,3
00327          IF(AHD.LT.CC(1,I))GO TO 22
00331       21 CONTINUE
00333          I=3
00334       22 CP=(AHD-CC(1,I-1))*(CC(2,I)-CC(2,I-1))/(CC(1,I)-CC(1,I-1))+CC(2,I-
00334         21)
00335          C = B *CP
00336          T = PT - ONT
00337          WRITE(6,401)T,F
00343      401 FORMAT(5H1T = ,F7.2/5H F = ,F7.2)
00343   C
00343   C      CALCULATION OF G
00343   C
00344          X1 = (B-A)/E
```

```
00345              XY1 = A
00346              X2 = (C-B)/(F-E)
00347              XY2 = B - X2*E
00350              CST1=(B+A)*(E/2.)
00351              CST2=(B+C)*((F-E)/2.)
00352              CSTS=CST1+CST2
00352         C
00352         C    CALCULATION OF DELTA CHARGE
00352         C
00353              IF(T.LT.TA)GO TO 7734
00355              AHD = FULCH - ONAHS
00356              IF(AHD.LE.CST1)GO TO 251
00360              IF(AHD.LE.CSTS)GO TO 252
00362              RE = AHD - CSTS
00363              G=(2.*RE)/(C+.4)+F
00364              WRITE(6,202)G
00367          202 FORMAT(4HOG =,F11.7)
00370              X3=(.4-C)/(G-F)
00371              XY3=C-X3*F
00372              IF(TA.GT.E)GO TO 27
00374              IF(T.GT.E)GO TO 25
00376              DELCH = X1*((T**2)/2.)+ XY1*T - X1*((TA**2)/2.)- XY1*TA
00377              AMPS = X1*T + XY1
00400              GO TO 30
00401          251 IF(T.LT.E)GO TO 253
00403              DELCH = FULCH - AHST
00404              AMPS = .4
00405              GO TO 30
00406          252 IF(T.LT.F)GO TO 254
00410              DELCH = FULCH - AHST
00411              AMPS = .4
00412              GO TO 30
00413          253 DELCH = X1*((T**2)/2.)+ XY1*T - X1*((TA**2)/2.)- XY1*TA
00414              AMPS = X1*T + XY1
00415              GO TO 257
00416          254 IF(T.GT.E)GO TO 255
00420              DELCH = X1*((T**2)/2.)+ XY1*T - X1*((TA**2)/2.)- XY1*TA
00421              AMPS = X1*T + XY1
00422              GO TO 30
00423          255 IF(TA.GT.E)GO TO 256
00425              DELCH = X1*((E**2)/2.) + XY1*E - X1*((TA**2)/2.)- XY1*TA
00426              DELCH = DELCH + X2*((T**2)/2.)+ XY2*T - X2*((E**2)/2.)- XY2*E
00427              AMPS = X2*T + XY2
00430              GO TO 257
00431          256 DELCH = X2*((T**2)/2.)+ XY2*T - X2*((TA**2)/2.)- XY2*TA
00432              AMPS = X2*T + XY2
00433          257 CALC = AHST + DELCH
00434              IF(CALC.GE.FULCH)GO TO 621
00436              GO TO 622
00437          621 DELCH = FULCH - AHST
00440              AMPS = .4
00441          622 GO TO 30
00442           25 IF(T.GT.F)GO TO 26
00444              DELCH = X1*((E**2)/2.) + XY1*E - X1*((TA**2)/2.)- XY1*TA
00445              DELCH = DELCH + X2*((T**2)/2.)+ XY2*T - X2*((E**2)/2.)- XY2*E
00446              AMPS = X2*T + XY2
00447              GO TO 30
00450           26 IF(T.GT.G)T = G
```

```
00452    177*            DELCH = X1*((E**2)/2.) + XY1*E - X1*((TA**2)/2.)- XY1*TA
00453    178*            DELCH = DELCH + CST2
00464    179*            DELCH = DELCH + X3*((T**2)/2.)+ XY3*T - X3*((F**2)/2.)- XY3*F
00455    180*            AMPS = X3*T + XY3
00456    181*            GO TO 30
00457    182*         27 IF(TA.GT.F)GO TO 29
00461    183*            IF(T.GT.F)GO TO 26
00463    184*            DELCH = X2*((T**2)/2.)+ XY2*T - X2*((TA**2)/2.)- XY2*TA
00464    185*            AMPS = X2*T + XY2
00465    186*            GO TO 30
00466    187*         26 IF(T.GT.G)T=G
00470    188*            DELCH = X2*((F**2)/2.)+ XY2*F - X2*((TA**2)/2.) - XY2*TA
00471    189*            DELCH = DELCH + X3*((T**2)/2.) + XY3*T - X3*((F**2)/2.) - XY3*F
00472    190*            AMPS = X3*T + XY3
00473    191*            GO TO 30
00474    192*         29 IF(T.GT.G)T = G
00476    193*            DELCH = X3*((T**2)/2.) + XY3*T - X3*((TA**2)/2.) - XY3*TA
00477    194*            AMPS = X3*T + XY3
00477    195*      C
00477    196*      C
00500    197*         30 DO 96 J = 2,3
00503    198*            IF(AMPS.LT.VI(1,J))GO TO 97
00505    199*         96 CONTINUE
00507    200*            J = 3
00510    201*         97 VOLTS = (AMPS - VI(1,J-1))*(VI(2,J)-VI(2,J-1))/(VI(1,J)-VI(1,J-1))
00510    202*           2 + VI(2,J-1)
00511    203*            WRITE(6,203)A,B,C,E,F,DELCH,TA,FT,CP
00524    204*        203 FORMAT(4HOA =,F11.7/1X,3HB =,F11.7/1X,3HC =,F11.7/1X,3HE =,F11.7/
00524    205*           21X,3HF =,F11.7/1X,7HDELCH =,F11.7/1X,4HTA =,F11.7/1X,4HFT =,F11.7/
00524    206*           31X,4HCP =,F11.7)
00524    207*      C
00524    208*      C     UPDATE
00524    209*      C
00525    210*            DO 31 I=1,3
00530    211*            IF(JBAT(I).EQ.1)GO TO 32
00532    212*         31 CONTINUE
00534    213*            GO TO 7734
00535    214*         32 AHS(I) = AHS(I) + DELCH
00536    215*            TL(I) = PT
00537    216*            AMP(I) = AMPS
00540    217*            VOLT(I) = VOLTS
00541    218*            IF(AHS(I).LT.FULCH)GO TO 7734
00543    219*         34 WRITE(6,35)
00545    220*         35 FORMAT(25H BATTERY IS FULLY CHARGED)
00546    221*       7734 WRITE(6,66)PT,TL,AHS,TD,ONTIM
00571    222*            WRITE(6,92)AMP,VOLT
00603    223*         92 FORMAT(1X,5H AMPS,10X,3F20.5/1X,6H VOLTS,9X,3F20.5)
00604    224*         66 FORMAT(13H0PRESENT TIME,F12.5//30X,1HA,20X,1HB,20X,1HC/1X,14H LAS
00604    225*           2T GET SOLN,1X,3F20.5/1X,11H A-H STATUS,4X,3F20.5/1X,15H LAST DISCH
00604    226*           3ARGE,3F20.5/1X,8H ON TIME,7X,3F20.5)
00605    227*         77 CONTINUE
00607    *DIAGNOSTIC*    THE RETURN STATEMENT IS ILLEGAL IN A MAIN PROGRAM. IT WAS CHANGED TO STOP.
00607    228*            RETURN
00610    229*            END

         END OF UNIVAC 1108 FORTRAN V COMPILATION.     1 *DIAGNOSTIC* MESSAGE(S)
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8.0 SAMPLE CASE

The battery charger output characteristic is presented in figure 8-1 as a function of the battery initial conditions. The initial conditions are given in table 8-I. Note from figure 8-1 that it takes 5.92 hours to recharge the CSM entry and postlanding battery which has been depleted by only 4 A-h. This recharge time is caused primarily by the very long time period of 22 hours from the time of last discharge to the time the battery charger was put on the battery. Very low starting and peak charger currents are also results of this long period of time between battery use and battery recharging.

TABLE 8-I.- ENTRY AND POSTLANDING BATTERY

INITIAL CONDITIONS

Conditions tested	Result of test
Battery A-h status at time of charging	36.0
Full charge A-h rating of battery	40.0
Time from end of last discharge, hr	22.0

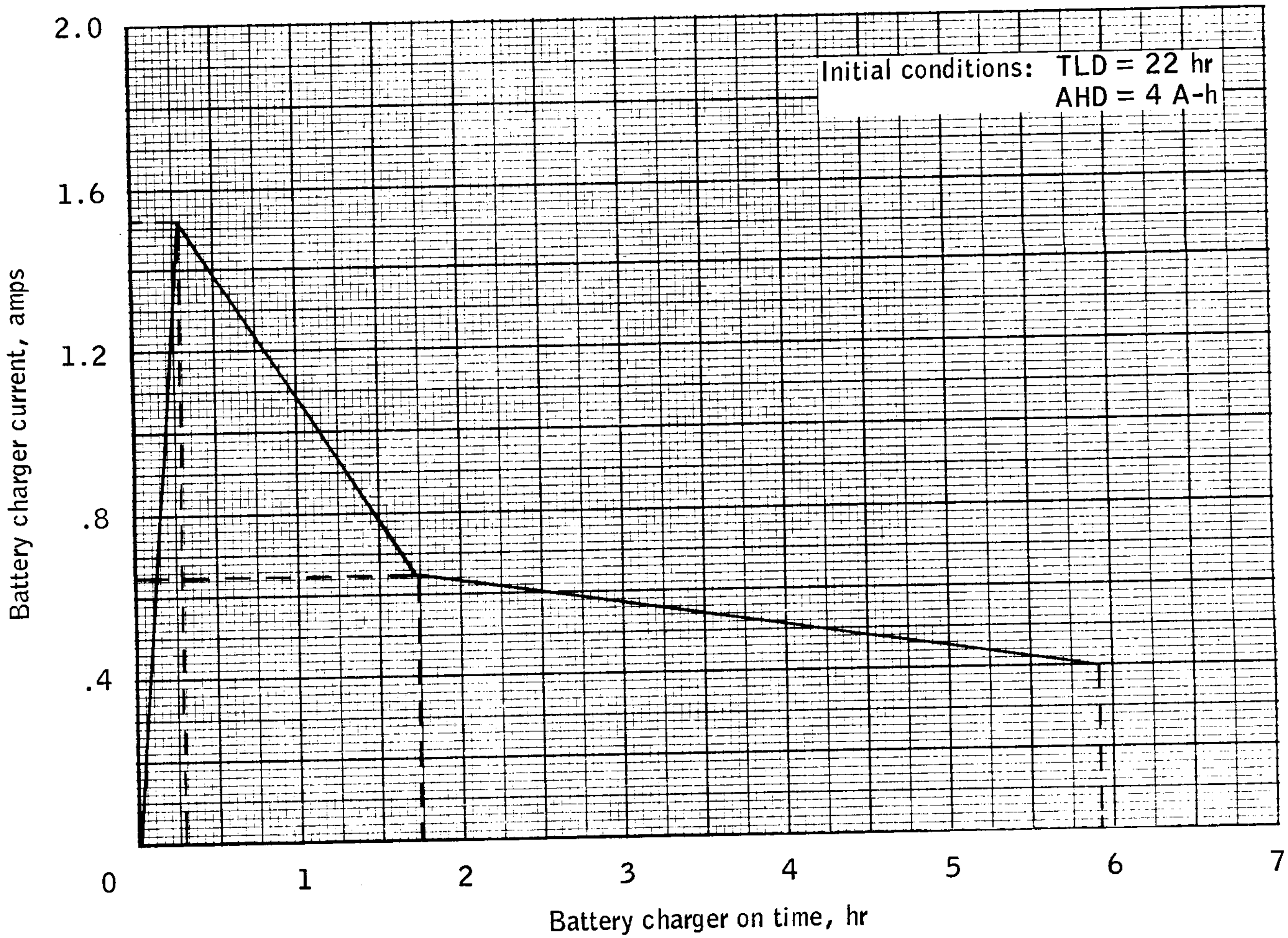

Figure 8-1.- Battery charger output profile.

9.0 BATTERY CHARGER MODEL DESIGN DATA

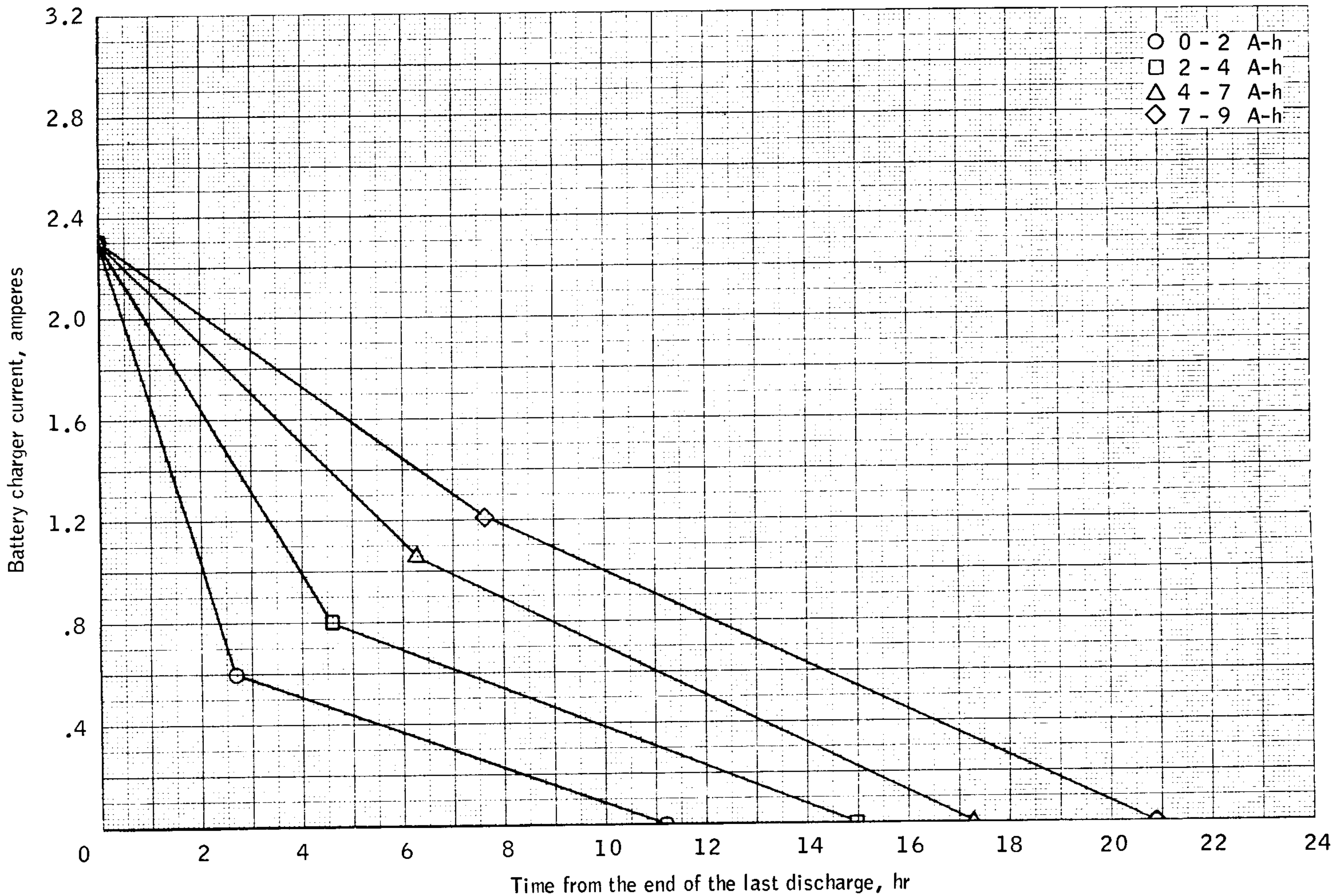

Figure 9-1.- Battery charger starting current co-ordinate A.

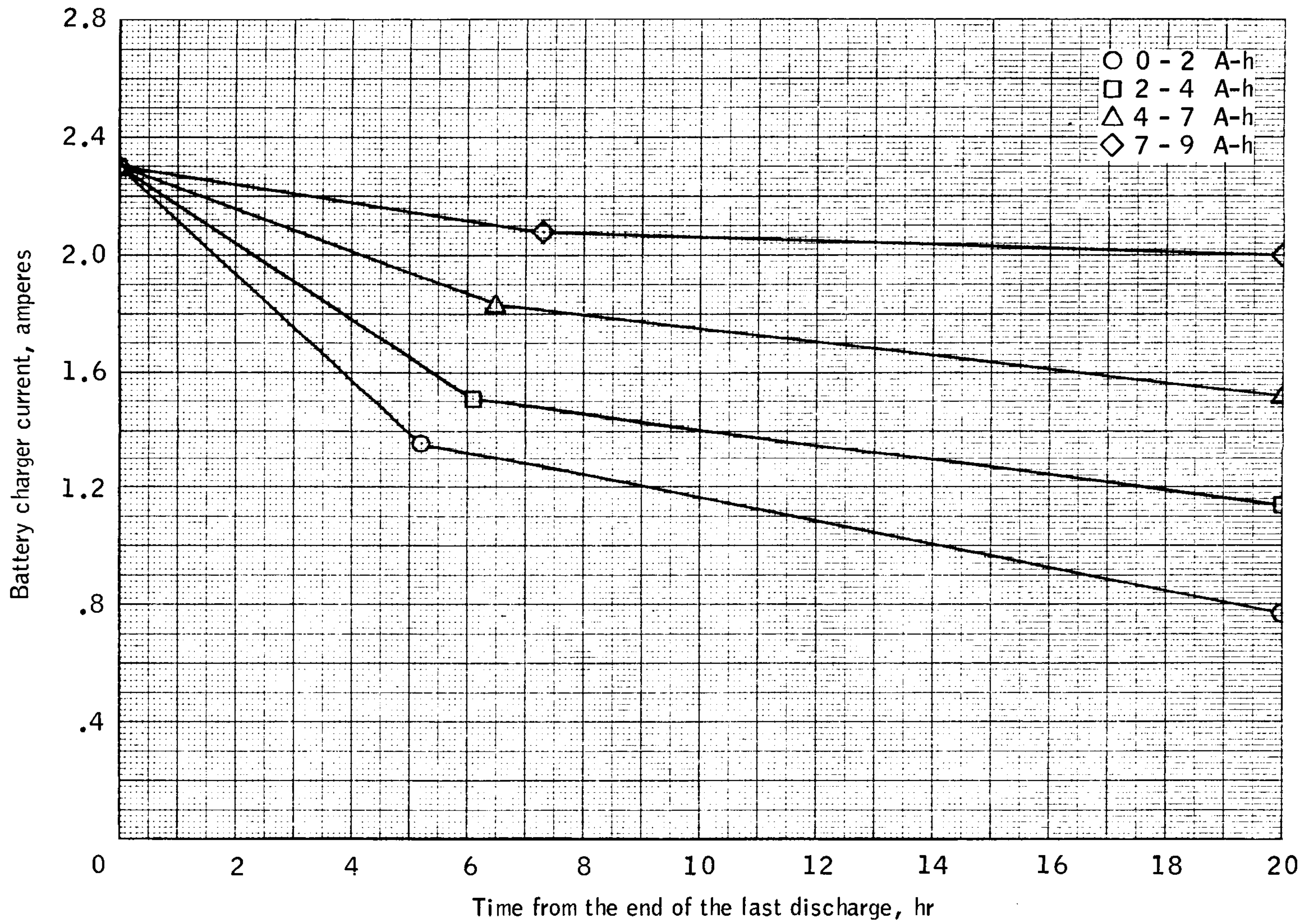

Figure 9-2.- Battery charger peak output current co-ordinate B.

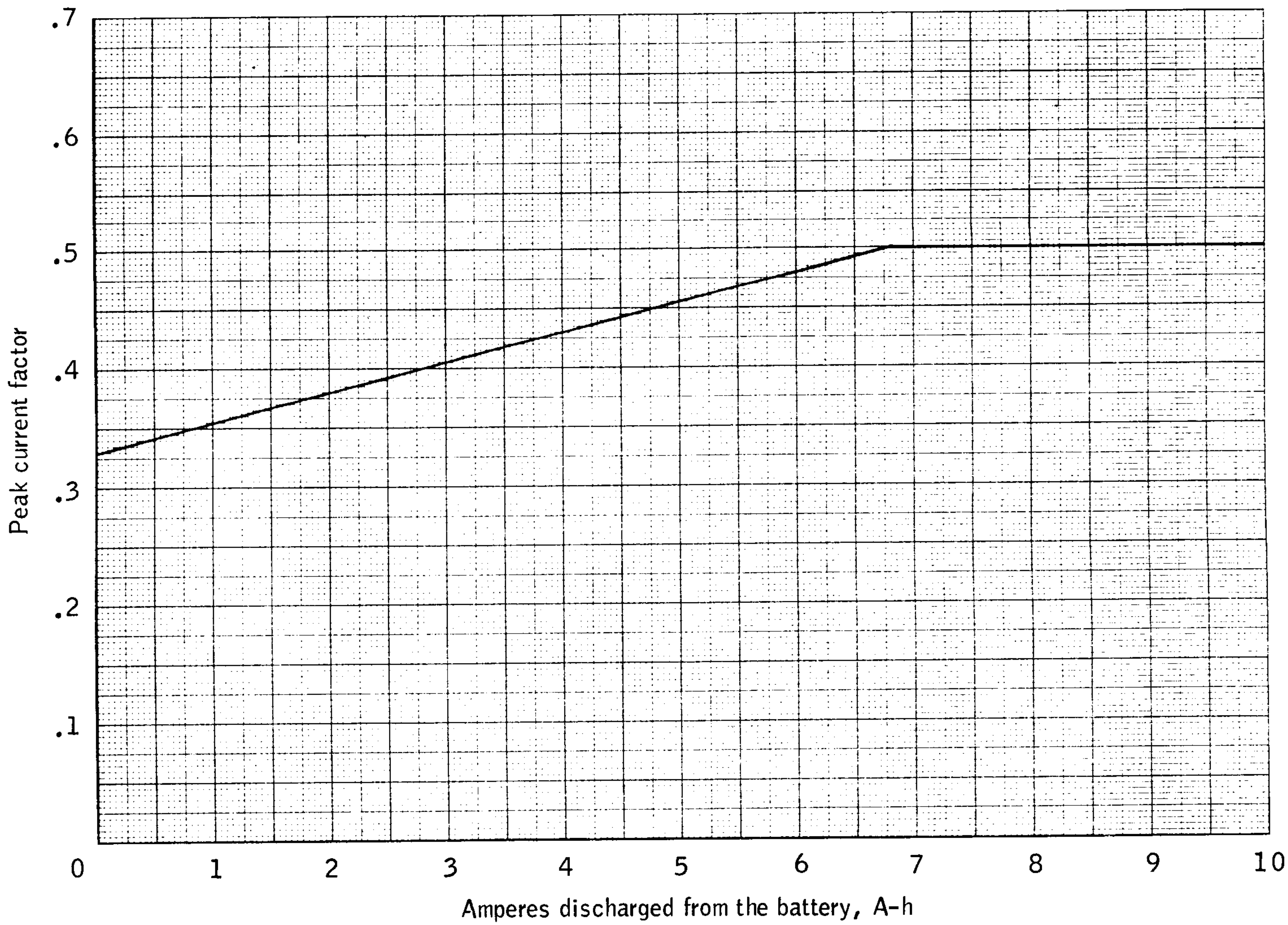

Figure 9-3.- Battery charger output current co-ordinate C peak current factor.

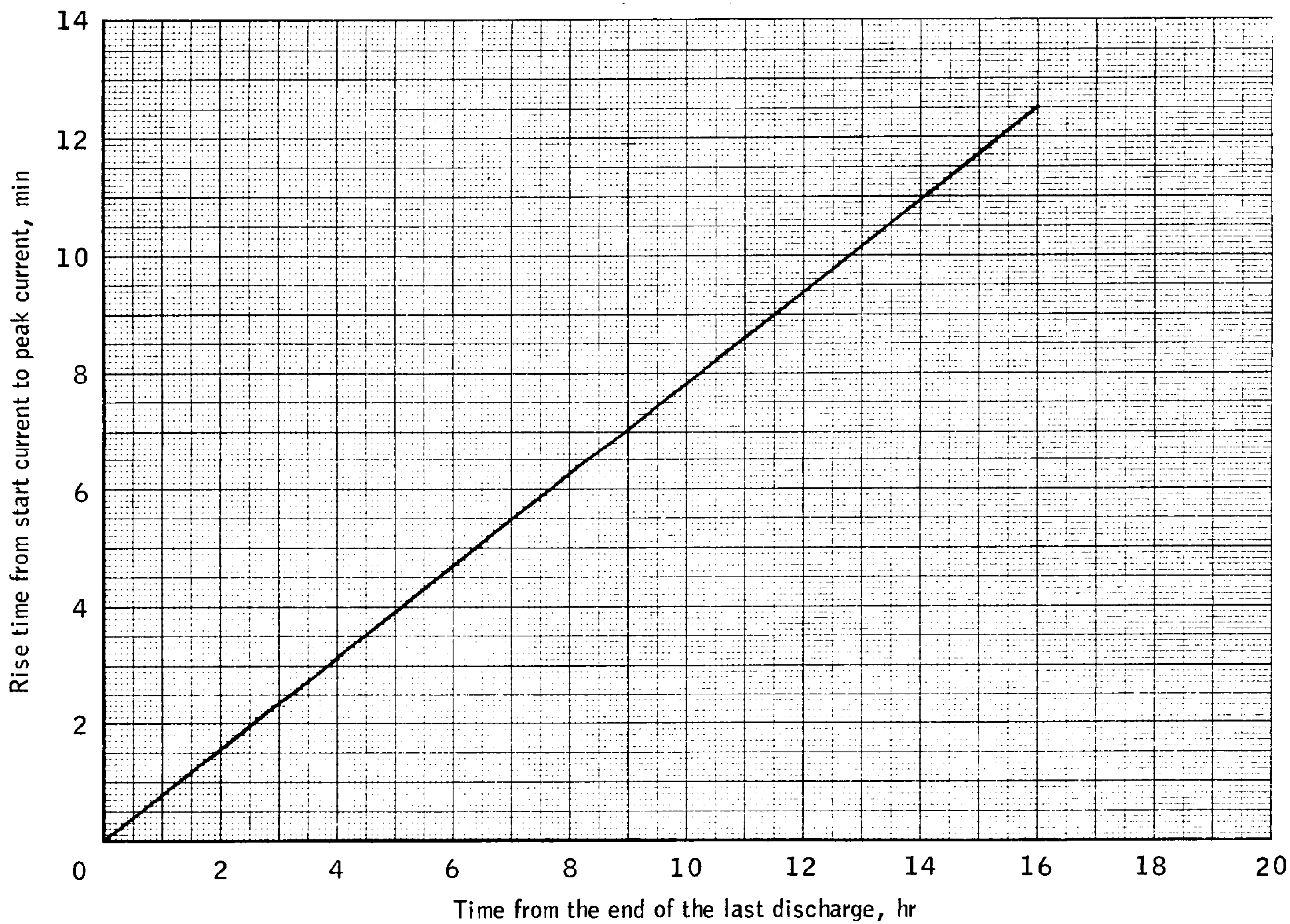

Figure 9-4.- Battery charger output current rise time from the starting current level to the peak current level co-ordinate E.

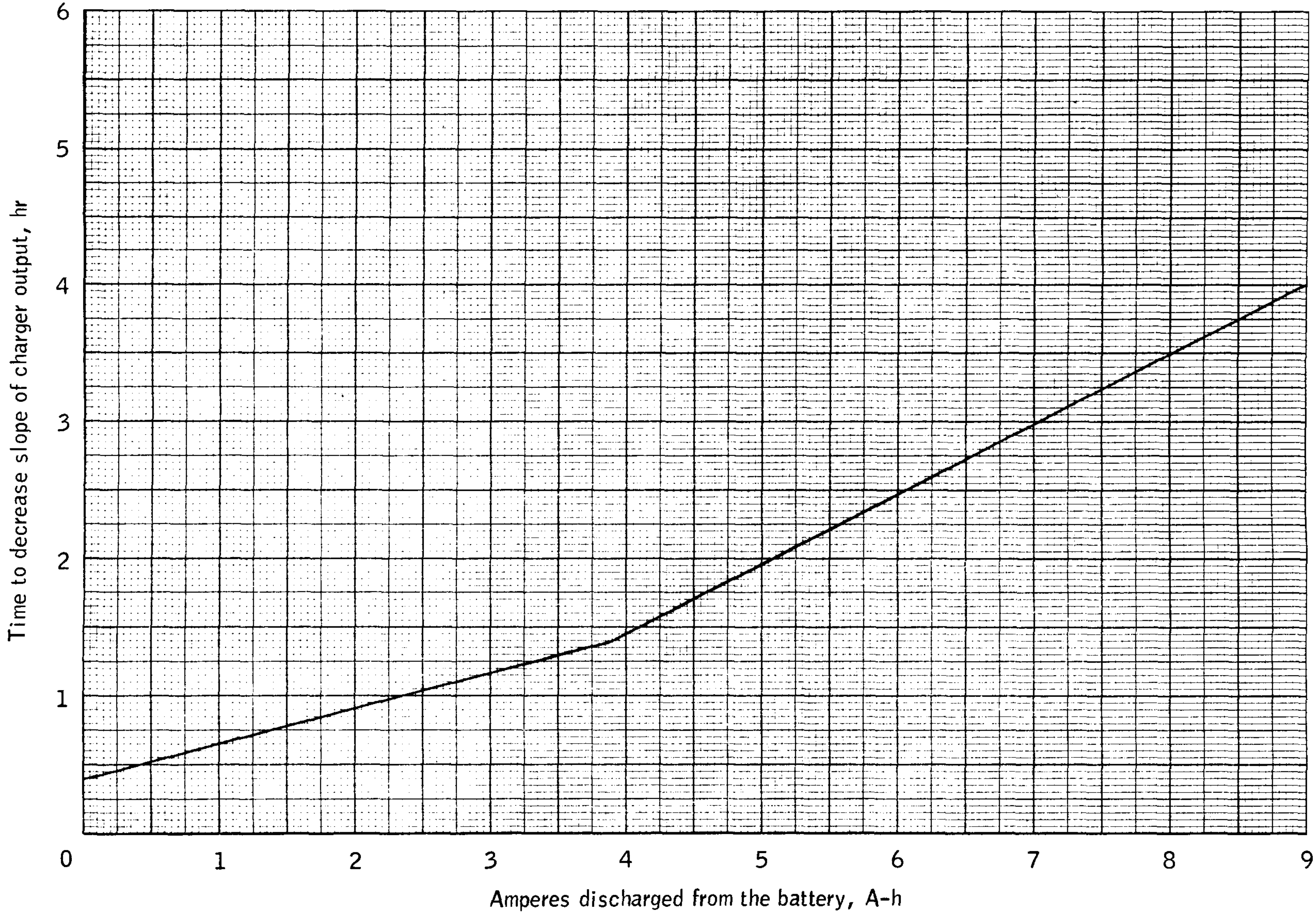

Figure 9-5.- Battery charger output co-ordinate F.

REFERENCES

1. Charge - Discharge Testing of the Entry and Post-Landing Battery and Spacecraft Battery Charger. MSC/IESD document 21-15, Revision A.

2. Spacecraft Operational Data Book, SNA-8-D-027(I) Rev I, Electrical Power Subsystem.